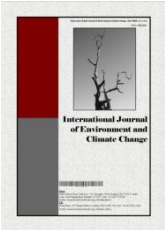

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Status of Precision Farming Technologies in Indian Context – A Review

P. Nikitha [a*], V. Sudha Rani [a], V. Ravinder Naik [a], B. Padmaja [a], A. Nirmala [a] and K. Aruna [a]

[a] College of Agriculture, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Rajendranagar, Hyderabad-500030, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Precision farming is a farm management method that involves using software technologies and principles to control spatial and temporal variability in all aspects of agricultural production in order to improve crop performance and environmental quality. It's quickly gaining traction in developed countries as a tool for addressing the issue of agricultural sustainability. Precision farming has been garnering greater attention in the Indian context as the digitization era in agriculture and horticulture has progressed. Though widely adopted in industrialised countries, it is still in its infancy in most developing countries, such as India, where it requires integrated and long-term efforts ranging from pre-harvest tillage to post-harvest handling of Agri - Horti crops. Knowledge of latest breakthroughs in the field of precision agriculture. The use of technology makes it easier to anticipate future issues. As a result, this article provides an overview of precision farming technology development and current state in India.

Keywords: Precision farming; information technology; crop production.

1. INTRODUCTION

Precision farming is one of the most scientific and up-to-date methods of farming for sustainable agriculture that gained traction as the twentieth century drew to a close. Precision farming is a control strategy that gathers, strategies, and analyses temporal, spatial, and

**Corresponding author: E-mail: nikithaagext@gmail.com;*

Table 1. Classification of Precision Farming (PF) Technologies

Data Collection Technologies	Data Process & Decision Making Technologies	Application Technologies
• Soil sampling and mapping • Yield monitoring and mapping • Remote sensing • Global satellite positioning • Geospatial Technology • Field/crop scouting	• GPS-GIS based farm management • Agricultural mapping software • Geoinformatics • Geostatistics • Crop modelling • Artificial Intelligence primarily based Controlling systems	• Variable-rate technology • Yield monitors • Agricultural robots • Wireless data logger and Sensor catalogue • Global Navigation Satellite system (GNSS) based guidance • Hyperspectral sensor based applications • Automated control system through Greenhouse and Polyhouse cultivation • Precision Lazer Land leveller • Mulching • Low Tunnel Technology/Walking Tunnels • Microirrigation • Site-specific Nutrient Management (SSNM) • Drone Technology

individual facets and combines it with other information to support management decisions in line with envisioned variability for stepped forward improved resource use performance, productivity, exceptional quality, profitability, and sustainability of agricultural production, according to the International Society on Precision Agriculture (ISPA) [1].

Technological developments in agricultural sector yield higher control practices resulting in more precision in agricultural operations from tillage to harvesting to reduce inputs, increase profits, and protects environment [2,3]. Knowledge poverty of the farmers is one of the trouble in developing nations. In order to face environmental, technical, infrastructural & social constraints associated with adoption of precision farming technologies that could manipulate and allocate all resources correctly for sustainable development of agriculture and horticulture is necessary. Precision farming isn't simply the injection of recent technologies however it's alternatively an information revolution, made possible by way of new technology that result in a better degree, a greater precise farm management system [4]. Precision farming basically is a method application of the right quantity of input at the proper time and at the right vicinity within a field area accurately. It is a scientific method to enhance the crop management by means of utility of Information Technology (IT) and satellite based technology to identify, analyze and manipulate the spatial and temporal variability of agronomic parameters (Eg. Soil, pest or disease, fertigation and so forth.) with in the field by using well timed utility of correct amount of inputs to optimize profitability, sustainability, with a minimized effect on environment [5].

The primary obstacles that are arising in our current stage of existence are dwindling land, depleting water, and other issues related to agricultural resources [6]. There is a need to promote farmer-friendly, site-specific production system management technologies in a concerted manner in order to achieve vertical growth in agricultural and horticultural production while ensuring quality of produce and higher remuneration per unit of area while minimizing natural resource consumption. In this endeavour, precision farming implies to have efficient utilization of resources by keeping in view of unit of time and area for attaining targeted production of agricultural and horticultural produce. The precision farming technology assures the productivity enhancement with decreasing the production cost through efficient utilization of resources [7]. Precision agricultural success is typically dependent on correct variability assessment, assessment, management, and evaluation in a crop's space and time continuum. Precision farming's major components include visualizing data at the appropriate scale and frequency, interpreting and analyzing records, and implementing management responses at the appropriate scale and time [8]. The application of cutting-edge scientific information technologies to imparting, processing, and analyzing multi-sectoral data of high spatial and temporal resolution for decision-making and operations in crop production management is the key differentiator between traditional farming and precision farming.

The purpose of this research was to review studies on precision farming technologies in the Indian setting and to compare precision farming strategies in terms of utility in application, decision support systems, and field data gathering and analysis approaches.

2. MATERIALS AND METHODS

The literature on the status of several precision farming (PF) technologies in the Indian context was gathered for this study. Following the review process, scientific journals, reports, books, and pertinent web pages were examined, and information on various Precision farming technologies in the Indian context was produced.

3. RESULTS AND DISCUSSION

a) Status of Precision farming technologies in Indian context – Research Findings

The literature review in Table 2 was based on published studies on various crops, forms of precision farming technologies, and analysis methodologies in the Indian setting. Ex-post approaches, as well as Logit and Probit methodologies predominate in these investigations.

The research findings evaluated so far in this comparative literature analysis show that Wireless Sensor Networks can be used constructively and effectively in precision farming. As a result, it's critical to design, analyse, and implement a system that considers the special needs of a given crop. Sensors and their associated interface systems can be used to monitor precision farming technologies accuracy. Table 3 summarises the current control and monitoring systems, as well as their modules for sensing micro weather factors.

Table 2. Research Findings of Precision farming technologies in India

Author	Publication year	Location & Crops	Studied PF Technology	Method of Analysis	Research Findings
Koch et al.	2004 [9]	Bihar state in Paddy	Variable Rate Technology	Logit analysis	When comparing the Site- specific Management Zones (SSMZ- Variable yield goal) N management method to uniform N management, the results showed that the Site-specific Management Zones (SSMZ- Variable yield goal) N management method required less N fertiliser. Because of the identification of site- specific management Zones, there is a decrease in N fertiliser use and an increase in N use efficiency.
Persson et al.	2005 [10]	Shimla state in Potato crop	Differential Global Positioning system (DGPS) Digital Elevatio n Model (DEM)	Logistic regression analysis	Topographical parameters were retrieved from the DEM, and topographical indices were predicted. The association between yield and topographical factors was explored, and the very last model for one of the fields was able to explain up to 20% of the yield.
Stamatiadis et al.	2005 [11]	Gujarat state in Cotton crop	Soil and crop sensors	Principal component analysis (PCA)	In a cotton field, ground- based sensors were employed to simultaneously monitor soil and canopy reflectance in the visible and near-infrared (VNIR). The PCA method was used to expose spatial soil variants from soil near-infrared reflectance (NIR) spectroscopy. Total carbon showed no spatial dependence, although clay content and pH did at a distance of fifty-four and forty-six metres, respectively.
Reyniers et al.	2006 [12]	Punjab & Haryana states in Winter Wheat crop	Airborne Data Acquisition and Registratio n (ADAR) remote sensing	Correlation & Regression analysis	To compare an aerial image with the optical aspects of a multi- spectral radiometer on a terrestrial platform. In comparison to the NDVI of the aerial system, the NDVI of the ground device was more closely associated to yield factors at harvest.For both systems, the best correlation coefficient was obtained with nitrogen in grain: 0.84 and 0.91 for the aerial- based and ground-based systems, respectively.
Mondal and Basu	2009 [13]	West Bengal state in Rice crop	Leaf color chart (LCC) based Nitrogen management	Split plot design	In rice, using the Leaf Color Chart for Nitrogen Use Efficiency (NUE) saves 25 kg/ha (19.40%) of nitrogen, with a very high saving of 314 kg/ha (21.00%) in the Boro season. It resulted in enhanced yields of 50, 60, and 90 kg/ha in the pre- kharif, kharif, and boro seasons,

Author	Publication year	Location & Crops	Studied PF Technology	Method of Analysis	Research Findings
					respectively. The size of insecticide packets has been cut by half.
Yang et al.	2011 [14]	Punjab state in Wheat crop	Remote sensing (Multispectal imagery)	Kappa analysis	According to the accuracy evaluation, using the short-wave infrared spectrum significantly improved overall accuracy from 82 percent to 91 percent. The pixel size was increased from 10 m to 20 m or 30 m with no obvious effect on crop identity type accuracy. These findings imply that utilising SPOT 5 multispectral pictures with maximum likelihood and SVM classification algorithms, crop types and regions may be predicted.
Manjeet Singh et al.	2013 [15]	Punjab state in rice crop	Yield monitoring system & Mappin g	Regression analysis	Three rice fields were harvested to evaluate the yield display's overall performance in terms of grain yield and moisture mapping of harvested grains. The real yield maps were created with the help of Arc GIS software. Within all three fields harvested, the minimum and greatest yields were 577.08 and 7,661.48 kg ha-1, respectively, with an average yield of 4,287.66 kg ha-1 and a 37.26 percent coefficient of variation (CV) in all three fields.
Pahuja et al.	2013 [16]	Punjab state in Horticultura l crops	Automated Control System in Green House	Greenhous advance microclimate monitoring and control software (GH- ACMCs) Collaborative data processing and statistical analysis like histogram, cumulative distribution frequency	With excellent information and packet dependability (85 to 100 percent) and low battery drop, WSN monitored and regulated a greenhouse climate (zero.03 V). The climate controller monitored the originally high internal VPD and reduced the cost to meet the most efficient conditions by running the devices only when they were needed. Furthermore, the real-time display of greenhouse climate-control data aided the grower in making better judgments when it came to performing greenhouse operations, resulting in healthier crop development and yields.
Karimi et al.	2014 [17]	Rajasthan state in Corn	Artificial Intelligence based control system	Remote hyperspectral image analysis	Support Vector Machines (SVM) and artificial neural networks (ANN) were used to detect and categorise weeds in a corn field with the goal of intelligently managing the quantity of nitrogen used for weed management. In comparison to the ANN, the SVM

Author	Publication year	Location & Crops	Studied PF Technology	Method of Analysis	Research Findings
					technique had low misclassification rates and a high generalisation capacity in the study. The conclusion reached is that SVM is an excellent tool for weed detection and control.
Halimi and Moussa	2015 [18]	Uttar Pradesh state in Potato crop	Robotic Greenhouse system for crop scouting	Radial Basis Function Networking analysis	The Guelph Intelligent Greenhouse Automation System (GIGAS) is a user-friendly robotics system with a wide range of applications in greenhouses. According to the research, GIGAS can reach a 92% production efficiency while increasing yields by 63%.
Durga et al.	2018 [19]	Telangana state in Rabi maize crop	Precise irrigation system using nano soil moisture sensors	Split plot design	Irrigation methods and irrigation timing were found to have a significant impact on maize plant tops, according to the study. Plant height was higher in drip- irrigated plots at 60, 90 DAS and harvest than in surface- irrigated plots. Due to the less frequent irrigation associated with tensiometer irrigation, dry matter output is reduced in tensiometer-based irrigation scheduling.
Kanannavar et al.	2020 [20]	Karnatak a state in Paddy	Precision Laser Land leveller technology	Uniformity coefficient analysis	The findings revealed a reduction in land levelling drudgery, a greater levelling index, and better homogeneity in soil- moisture distribution. It was reported that farming using precision lazer land leveler may increase paddy output by 25 to 35 percent while saving water by 25 to 30 percent, labour by 30 to 40 percent, and electricity by 30 to 40 percent.
Arti Verma	2021 [21]	Punjab state in Capsicum crop	Low Tunnel Technology	Randomized Block Design (RBD)	The results of the study show that growing the PSM-1 variety in low tunnels is a viable strategy, yielding 82 quintals per acre.
Padmaja et al.	2021 [22]	Telangan a state in Cucumber crop	Dri p & Fertigation	Split plot design	At 150 percent of the approved dose of NK, yield attributes were significantly greater than at 75 percent of the recommended dose of NK. Fruit output was significantly greater at 150 percent recommended NK dose (76.70 t ha^{-1}) than at 75 percent recommended dose (60.30 t ha^{-1}) and comparable to both 125 percent and 100 percent recommended doses of NK. Drip irrigation at 0.8 Epan (28.6 kg m^{-3}) was more efficient than 1.2 Epan (27.2 kg m^{-3}) or 1.0 Epan (28.6 kg m^{-3})

Author	Publication year	Location & Crops	Studied PF Technology	Method of Analysis	Research Findings
					irrigation (26.6 kg m^{-3}). The water use efficiency of 150 percent recommended dose of NK was significantly greater (30.1 kg m^{-3}) than the water use efficiency of 75 percent recommended dose of NK (23.5 kg m^{-3}).
Subramanian et al.	2021 [23]	Tamil Nadu state in rice crop	Drone technology	Coefficient of variation	During the planting season of September 2020, the efficacy of pesticide spray (fungicide copper oxychloride 53.8 percent @ 35 g 16 L1 against bacterial and fungal diseases) in rice fields utilising drones was demonstrated. The best flying height (3 m), speed (5 m s1), swath (4 m), and area coverage (4 min acre1), according to preliminary study, are as follows: It shows that drone-assisted pesticide spraying is a promising new method for overcoming labour shortages and accelerating plant protection measures.

Table 3. Classification of existing control and monitoring systems and its modules for sensing Microclimate

References	Sensors interfaced	Technology	Monitoring system	Module interfaced
Irmak et al. [24]	Light, moisture and temperature, soil moisture, Humidity, CO2, illumination	ZigBee, Internet	PC, Laptop	ZigBee module 3160
Tan and Panda [25]	Humidity, illumination, Temperature	ZigBee, internet	Laptop	CC2420, MSP430
Sabri et al. [26]	Temperature, humidity	ZigBee, SunplusSPCE061A	TFT-LCD	Chip (SoC)
Kim et al. [27]	Temperature moisture and soil	ZigBee, GPRS	Mobile phone	JN5121, ARM9
Rani Kamalesh [28]	Temperature, soil temperature and moisture, Humidity, Anemometer, illumination, rain gauge	ZigBee, Internet	Laptop, PDA	MSENS SoC
Navaro et al. [29]	Temperature, humidity, PH	Sensor node(mono-chip sensors)	-	RF CC3271 PSOC kit
Sai et al. [30]	Temperature, humidity	ZigBee	PC, Matlab 7.0	PECRP

4. CONCLUSION

In precision farming, to acquire incredible merchandise in agricultural and horticultural crops, the soil, crop, environmental parameters have to be effectively monitored and managed to provide best values related to productivity, profitability, resource use efficiency, environmental sustainability and so on. Hence A review on status of precision farming technologies in Indian context primarily based on remote monitoring and manipulate strategies had been presented. A unique comparison of diverse decision- making systems employed for precision farming including ANN, DGPS, LCC, ADAR, Bayes, SVM, Remote sensing, mapping technologies and modules used for monitoring sensor information which includes ZigBee, net, GSM and RFID have also been looked at in terms of water and soil requirements. Precision irrigation, nitrogen and fertilizer planning and management for yield optimization, early identification and eradication of crop weeds, illnesses, and pests, and evaluation of crop production forecast are all areas where software computers can be used. The review investigations revealed that by implementing a Wireless Sensor Network with the valuable resource of a discrete, smart, intuitive decision making and control protocol for successful yield production and irrigation management, some of the obstacles encountered in precision farming can be tamed. As a result, future precision farming adoption strategies in India must take into account land fragmentation, the loss of rather state-of-the-art technical centres for precision farming, specific software programmes for precision farming, the poor financial situation of the average Indian farmer, and so on. Integrating farmer know-how, precision farming equipment, and crop simulation modelling to evaluate management alternatives for underperforming regions in cropping fields can be a wonderful option for developing countries like India.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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